



528313

April 2001 Progress Report

**Technical Status Report**

**Low Temperature, Reverse Brayton Cryocooler**

**Contract No.: NAS5-97027**

**Period of Performance: April 2001**

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Project 8141  
May 17, 2001

## 1 INTRODUCTION AND SUMMARY

This report describes the technical progress during the fifty-second month (April 1-30, 2001) of a project to develop a low temperature, reverse-Brayton cryocooler using turbomachines. The program is being conducted under the sponsorship of NASA Goddard Space Flight Center under contract NAS5-97027. Key personnel at Creare are: Walter Swift – Program Manager, Dr. Mark Zagarola – Systems Engineer, and Drs. Herbert Sixsmith and John McCormick – turbomachine development. Ms. Judith Gibbon is the Technical Monitor at NASA Goddard.

This is a multi-year program to develop several low temperature cryocoolers, using unique heat exchanger and turbomachine technology in reverse Brayton refrigeration cycle configurations. The technology is an extension of prior work performed for NASA and the Department of Defense, in which a 5 Watt (W), 65 Kelvin (K) Single Stage Reverse Brayton (SSRB) cryocooler has been developed and demonstrated. Critical components for the 5 W SSRB were developed on SBIR contracts, culminating in the production of an Engineering Model of the cooler (contract NAS5-31281). The present effort is directed toward producing low vibration, long life coolers designed for refrigeration loads of 5 mW – 100 mW, at temperatures as low as 5 K. In order to meet these new, low temperature requirements, several technology advancements will be employed in the system components. These technologies have been developed on two NASA SBIR contracts.

- 1) The two key turbomachines, the compressor and the turbine, have been substantially redesigned to improve thermodynamic performance at lower flow rates. This involves the introduction of permanent magnets in the rotors and reduced size to improve efficiency. A major part of this technology was developed under NAS5-38066, in which a miniature turboalternator was designed, built, and tested at cryogenic temperatures.
- 2) A new heat exchanger configuration will be used for the recuperator(s). The new design involves a modular, radial flow architecture that substantially reduces size and mass while preserving the required heat transfer performance. This design is presently being developed under NAS5-33228. Key features of the design were demonstrated during Phase I of the SBIR contract.

The current program consists of a Basic Phase and four Option Phases. Each of the Phases is directed to a particular load/temperature combination. The technology and fundamental design features of the components used in these systems are related but differ somewhat in size, speed, and some details in physical geometry. Each of the Phases can be carried out independently of the others except that all proposed Phases rely on the technology developed and demonstrated during the Basic Phase.

The Basic Phase includes the demonstration of a critical component and the production of a prototype model cryocooler. The critical technology demonstration will be the test of a small turboalternator over a range of conditions at a nominal temperature of 6 K. These tests will provide design verification data useful for the further design of the other coolers. The prototype

model cooler will be designed to provide at least 5 mW of cooling at 6 K. The heat rejection temperature for this requirement is 220 K or greater. The input power to the system at these conditions is to be less than 60 W.

Options 1, 2, and 3 involve the design, fabrication, test, and delivery of cryocoolers with the nominal performance characteristics that are listed together with requirements for the Basic Phase cooler in Table 1 below. Option 4 involves the supply of a cooler that has the same requirements as the Basic Phase system.

<b>Table 1. Nominal Performance Characteristics</b>				
	<b>Basic</b>	<b>Option 1</b>	<b>Option 2</b>	<b>Option 3</b>
Refrigeration Temperature	6 K – 10 K	6 K – 10 K	6 K – 10 K	6 K – 10 K
Cooling Load	> 5 mW	> 20 mW	> 50 mW	> 5 mW
Rejection Temperature	> 220 K	300 K +/-	300 K +/-	> 100 K
Input Power	< 60 W	< 150 W	< 200 W	< 15 W

Following the completion of cryogenic tests at Creare on each of the systems above (Basic, Option 1, Option 2, and Option 3), the coolers will be shipped to one or more government facilities for EMI characterization tests, thermal qualification tests, vibration tests, and life tests, all supported by Creare personnel. In Option 4, additional coolers will be built with the intent that they are integrated and tested with detectors and/or instruments.

This report discusses activities that were performed during April on the Basic Phase of this contract.

## **2 STATUS AND PLANS – BASIC PHASE – 5 mW COOLER**

### **1000.1.2 PROJECT MANAGEMENT**

An internal project status meeting was held at the beginning of the month. The status, schedule and budget for each task were discussed during the meeting. The following sections summarize the status of the tasks.

### **1000.1.3 SYSTEMS ENGINEERING**

#### **Systems Engineering**

No work was performed on this task.

#### **Systems Analysis & Design**

Documentation of the system performance model was started. The model will be used to predict the system performance with the as-built High-Specific-Speed Turboalternator (HSSTA) and the brassboard compressors.

### **Contamination Control**

We began to assemble the hardware that will be used to remove water and other contaminants from the LTRBC cryocooler before it is tested cryogenically.

### **Compressor Development**

The effort to build a test rig for thrust bearing adjustment in the new compressors has been put on hold. Detail drawings for the test rig are being finalized but parts will not be fabricated at this time. From the present time, up to the system test, the task will encompass any necessary preparations of the two existing brassboard compressors for the system test. Some work was done in April on preparation of the test rig drawings.

### **Turbine Development**

The accumulators and check valves that protect the turbine thrust bearing from loss of supply during an emergency shutdown of the compressor were tested in April. Results of the tests showed:

- (1) The check valves, when open, have low pressure drop (less than 0.25 psi) at prototypical thrust bearing flowrates.
- (2) The check valves close properly to prevent backflow in the event of a loss of upstream pressure.
- (3) The volumes of the accumulators can maintain flow to the thrust bearings for eight seconds after the check valve closes in a loss of pressure event. This is substantially longer than the time it takes the turbine shaft to coast down to zero speed.

No further work is planned for this task.

### **Turboalternator Supplemental Testing**

A report was completed and delivered to NASA that summarizes the High-Specific-Speed Turboalternator (HSSTA) tests at 10 K and the Low-Specific-Speed Turboalternator (LSSTA) tests at 29 to 77 K. No further work is planned on this task.

### **Internal Reviews**

No work was performed on this task.

### **Government Reviews**

No work was performed on this task.

**1000.1.4 DESIGN****Design Inverter**

This task is closed.

**Design Turboalternator**

Drawings were revised to document the detail changes made during development testing.

**Design Compressor**

Detail drafting is complete for the compressor.

**Design Heat Exchanger**

No work was performed on this task.

**Design Cooler**

A small amount of work was performed on this task to document the cooler assembly.

**GSE Design**

No work was performed on this task.

**Design Support**

No work was performed on this task.

**1000.1.5 COOLER FABRICATION AND ASSEMBLY****Production Engineering & Planning**

Activity in April consisted of coordinating the completion of Recuperator fabrication.

**Inverter Fabrication**

No work was performed on this task.

**Turboalternator Fabrication**

No work was performed on this task.

**Compressor Fabrication**

No work was performed on this task.

### **Heat Exchanger Fabrication**

The final braze, to repair two small leaks previously detected in the third 200 plate Recuperator, was completed. The Recuperator was then installed into the shell and welded in place. Final leak tests were performed. This completes activity on the Heat Exchanger fabrication task.

### **Cooler Assembly and Integration**

We continued to assemble the test facility that will be used to measure the performance of the LTRBC cryocooler.

## **1000.1.6 GSE FABRICATION, ASSEMBLY TEST AND INTEGRATION**

### **GSE Fabrication, Assembly and Test**

Work on this task was largely completed in April. Activities focused on the first stage compressor inverter. The inverter V to F circuit was modified in order to provide a constant frequency output.

Additional work was performed to complete the thermocouple harness and rewire connections within the EGSE rack for the system test.

### **Software**

The software task was also largely completed in April. Remaining items include testing the software with actual instruments installed and wrapping up the documentation.

## **1000.1.7 COOLER SYSTEM TEST**

### **Test Planning and Procedures**

A draft of the cryogenic system test procedure was completed. The procedure will be reviewed and revised during May.

### **Cryogenic System Test**

No work was performed on this task.

## **1000.1.8 PRODUCT ASSURANCE**

### **Parts Engineering**

No work was performed on this task.

### **Materials and Processing**

A procedure to document the adjustment of tilt-pad bearings was drafted and is being reviewed.

### **Quality Engineering**

New and revised drawings were copied and distributed.

### **In Process Inspection**

No work was performed on this task

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